2. BIOLOGICAL CONDITIONS

2.1 Covered Species

The HCP provides for a conservation strategy for three federally listed species (Table 2.1). Based on the best available scientific information on each of the covered species, future development on Big Pine Key has the greatest probability of impacting the Key deer. The Florida Key deer has been used as umbrella species in the analysis conducted for this Plan. A brief description of the covered species follows.

Table 2.1. Covered species.

Common Name	Scientific Name	Federal Status
Key deer	*Odocoileus virginianus clavium*	E
Lower Keys marsh rabbit	*Sylvilagus palustris hefneri*	E
Eastern indigo snake	*Drymarchon corais couperi*	T

E=Endangered, T=Threatened

2.1.1 Florida Key Deer (*Odocoileus virginianus clavium*)

Description

The Florida Key deer is the smallest race of North American white-tailed deer. Key deer are morphologically distinct from other races of white-tailed deer and exhibit a stocky body, with shorter legs and a wider skull. Mature adults measure between 25 to 30 inches at the shoulder with average weights of 55 to 75 pounds for males, and 45 to 65 pounds for females. The Key deer's primary food source is the red and black mangrove, but they also feed on approximately 160 other plants to meet nutritional requirements (Klimstra and Dooley 1990).

Compared to northern white-tailed deer, Key deer are more solitary (Harding 1974). Home ranges average about 299 acres (greater during the breeding season) for male deer and 138 acres for females. The breeding season begins in September, peaks in October, and declines through December and January, while the peak of fawning coincides with the onset of the rainy season in April and May (Harding 1974, Silvy 1975). Factors resulting in the low reproductive performance of Key deer include low fecundity and reproductive activity as well as high fetal sex ratios and mean age of initial reproduction (Folk and Klimstra 1991b).

Distribution

The Key deer are wide ranging and utilize virtually all available habitat in the project area, including developed areas (Figure 2.1, Lopez 2001). The principal factor influencing the distribution and movement of Key deer is the location and availability of fresh water. Deer swim easily between keys and use all islands during the wet season when drinking water is available, but congregate on large islands during the dry season (Folk and Klimstra 1991a, Silvy 1975). Permanent deer populations are found on islands with extensive pine and hardwood habitats in addition to a year-round supply of fresh water (Klimstra and Harding 1978). Hammocks provide important cover for fawning and bedding, whereas open developed areas are used for feeding and resting.

Key deer have been documented as permanent residents throughout Big Pine, Big Torch, Cudjoe, Howe, Little Pine, Little Torch, Middle Torch, No Name, Sugarloaf, and Summerland Keys. Big Pine Key (5,840 acres) and No Name Key (1,191 acres) support more than two-thirds of the entire population, and both islands have permanent fresh water and extensive pineland habitat. Other keys receive transient use as a result of the lack of a permanent supply of fresh water: Annette, Big Munson, Little Munson, Johnson, Knockemdown, Mayo, Porpoise, Ramrod, Toptree Hammock, Wahoo, Water Key (east) and Water Keys (west).

Habitat

Development has led to the presence of patchy habitats where not all deer requirements are met in a single area, thereby increasing the movements of Key deer (Silvy 1975). Human-related mortality, primarily road kills, is the greatest known source of deer loss and accounts for about 50 percent of identified deaths, or an average of 44 animals per year (Lopez 2001). The current Key deer population on Big Pine Key and No Name Key is estimated at 453-517 animals (Lopez 2001), compared to 151 to 191 animals in the 1970s (Silvy 1975) and 25 to 80 animals in 1955 (Dickson 1955). The greatest impact on Key deer is the loss of habitat to development. Other factors include road kills, mortality of young from falling into drainage ditches, and predation by free-roaming dogs (Folk 1991, Lopez 2001).

2.1.2 Lower Keys Marsh Rabbit (*Sylvilagus palustris hefneri*)

The Lower Keys marsh rabbit is listed as endangered by both the Service and the FWC.

Description

The Lower Keys marsh rabbit is a subspecies of the marsh rabbit (*Sylvilagus palustris*) and is discernible from the adjacent Upper Keys subspecies (*Sylvilagus palustris paludicola*) by its skull proportions, sculpturing, and darker coloration (Lazell 1984). The Lower Keys marsh rabbit has a shorter molariform tooth row, higher and more convex frontonasal profile, broader cranium, and elongated dentary symphysis. The body is 12 to 15 inches in length with short dark brown dorsal fur and gray-white ventral fur. The tail is dark brown and inconspicuous. Hind feet range from two and one-half to three inches while the ears range from 1.7 to 2.4 inches (Forys 1996).

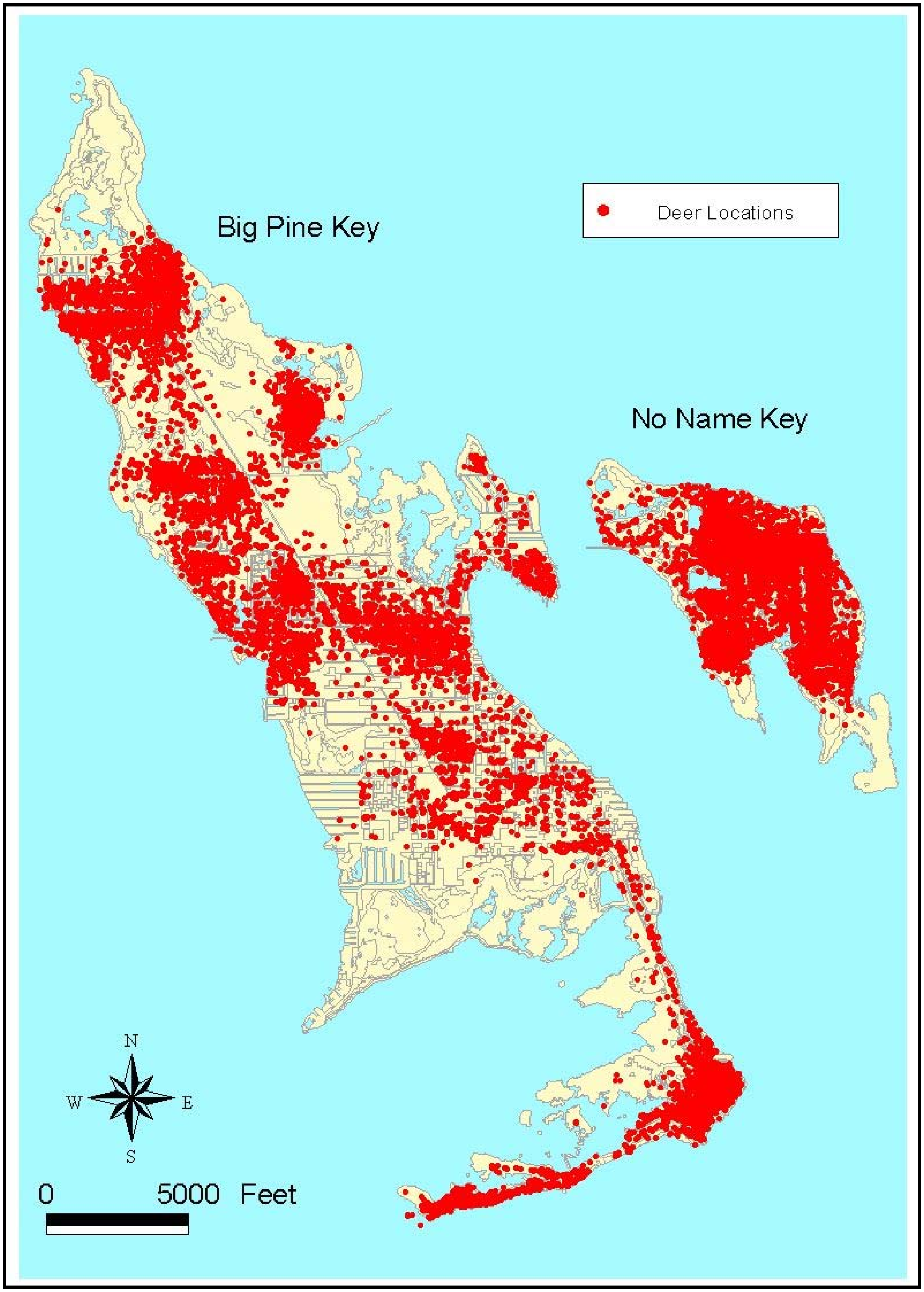

Figure 2.1. Key deer locations from telemetry data (Lopez 2001)

The Lower Keys rabbit is most active at night, in early morning or late afternoon, or during overcast weather. It feeds on a variety of plants, including leaves, shoots, buds, and flowers of grasses, herbaceous, and woody plants. Breeding behavior includes chasing of inferior males and receptive females by dominant males. In late summer, adult rabbits may chase young from the nest area.

Distribution

The Lower Keys marsh rabbit is presently known from many of the larger Lower Keys including Sugarloaf, Saddlebunch, Boca Chica, and Big Pine Keys and the small islands near these keys (Forys et al. 1996). Historically, the species may also have existed on Cudjoe, Ramrod, Middle Torch, Big Torch, and Key West Keys, but has been extirpated from these areas (Lazell 1984). The Lower Keys marsh rabbit probably occurred on all of the Lower Keys that supported suitable habitat but did not occur east of the Seven-mile Bridge where it is replaced by *S. p. paludicola*. Known localities for the rabbit are on privately owned land, state-owned land, and federal land within the National Key Deer Refuge and Key West Naval Air Station. In 1995, a comprehensive survey for Lower Keys marsh rabbits located 81 areas comprising 783 acres that provided suitable habitat, with 50 of these areas occupied (Forys et al. 1996). Suitable habitat for this species is highly fragmented across all of the Lower Keys.

Natural marsh habitats are limited in the Florida Keys, and have decreased in total area due to development for residential, commercial, or military-related purposes. Since the rabbit occurs in small, relatively disjunct populations, has a low population density, and is subject to predation by domestic predators, the species is in danger of extinction. Predation by domestic cats is the principal cause of mortality. Some road mortality occurs as rabbits attempt to move among increasingly isolated Lower Keys marshes. In the past, the Lower Keys rabbit was often hunted by man; this is not known to be a current threat. Connectivity among suitable habitat patches is necessary for marsh rabbit dispersal among patches, and isolation from domestic predators is perhaps the main factor to help this species survive (Forys and Humphrey 1994).

Habitat

Lower Keys marsh rabbit habitat occurs in saltmarshes and buttonwood areas throughout Big Pine Key (Figure 2.2). The species primarily occurs in grassy marshes and prairies of the Lower Keys in the middle of the salinity gradient but also includes less saline areas and the beach berm habitat. The Lower Keys marsh rabbit builds mazes of runs, dens, and nests in coastal (saline to brackish) or freshwater, inland marsh habitats. Two plant

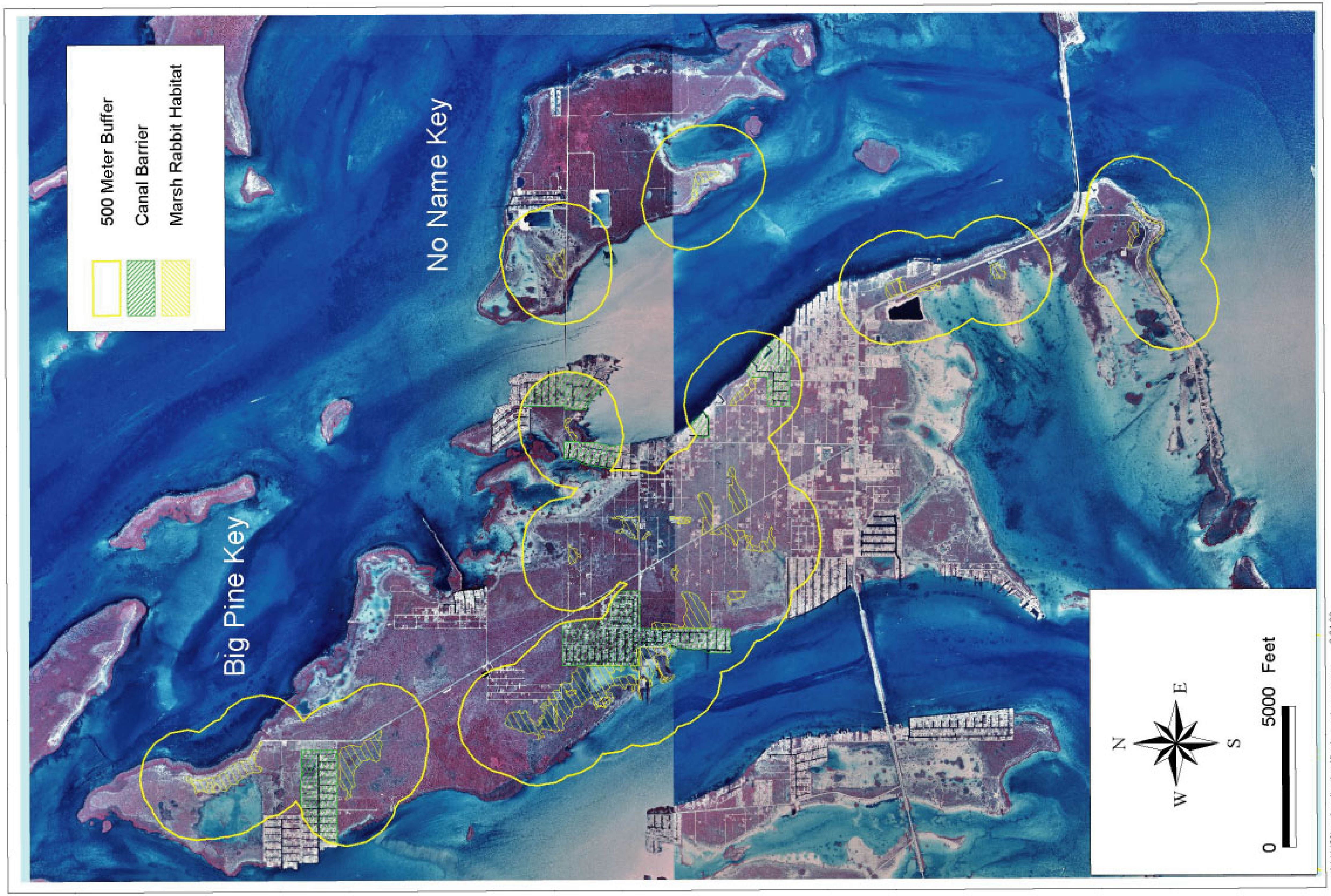

Figure 2.2. Marsh rabbit habitat

species, fringerush (*Fimbristylis* sp.) and bottonwood (*Conocarpus erecta*), are always present in the rabbit's habitat. In freshwater marshes, cattails (*Typha latifolia*), sawgrass (*Cladium jamaicense*), and sedges (*Cyperus* sp.) are common associates. Sometimes, spikerush (*Eleocharis* sp.) is also found. In coastal marshes, common associates include cordgrass (*Spartina* sp.), saltwort (*Batis maritima*), glasswort (*Salicornia virginica*), sawgrass (*Cladium jamaicense*), and sea ox-eye daisy (*Borrichia frutescens*). The rabbit's runs, dens and nests are made in cordgrass or sedges. Nests are lined with belly hair.

2.1.3 Eastern Indigo Snake (*Drymarchon corais couperi)*

On January 31, 1978, the eastern indigo snake was designated as threatened throughout its entire range.

Description

The eastern indigo snake is a large, non-poisonous snake that grows to a maximum length of eight feet. The color in both young and adults is shiny bluish-black, including the belly, with some red or cream coloring about the chin and sides of the head. The indigo subdues its prey (including venomous snakes) through the use of its powerful jaws, swallowing the prey usually still alive. Food items include snakes, frogs, salamanders, toads, small mammals, birds, and young turtles.

Distribution

Currently, the species is known to occur throughout Florida, except in the Marquesas and Dry Tortugas. The indigo snake is wide ranging and may cover between 125 to 250 acres.

Habitat

The indigo snake seems to be strongly associated with high, dry, well-drained sandy soils, closely paralleling the sandhill habitat preferred by the gopher tortoise. It is also known to occur in mangrove swamps, wet prairie, xeric pinelands and scrub (Cox and Kautz 2000). During warmer months, indigo snakes also frequent streams and swamps, and individuals are occasionally found in flat woods. Gopher tortoise burrows and other subterranean cavities are commonly used as dens and for egg laying.

2.2 Vegetation and Habitat

Mangroves and buttonwood saltwater wetlands are the most abundant habitat types in the project area, and account for 40 percent and 48 percent of Big Pine Key and No Name Key, respectively (Figure 2.3, Table 2.2). Uplands, including pinelands and hammocks, are the second most abundant habitat type and cover 29 percent of Big Pine Key and 48 percent of No Name Key. Developed areas are the least abundant habitat type and cover

19 percent of Big Pine Key and five percent of No Name Key. Freshwater wetlands are found in the central and northern portions of Big Pine Key.

Table 2.2. Habitat type distribution within the project area

		Percent Area	
Habitat type	**ADID categories[1]**	**Big Pine Key**	**No Name Key**
Pinelands	Pinelands	22	12
Hammocks	Hammocks, ridge/hammock	7	36
Freshwater Wetland	Freshwater marsh, freshwater hardwoods, freshwater pine	12	-
Buttonwoods	Buttonwoods, grasslands, saltmarsh	15	12
Mangrove	Mangrove, scrub mangrove	25	36
Developed	Developed, exotics	19	4
		100	100

[1] ADID: Advance Identification of Wetlands (FMRI 1995).

The Florida Keys Advance Identification of Wetlands (ADID) Project (McNeese and Taylor 1998) was the source map to develop a vegetation map of the project area. All land with the project area was field-verified and ADID habitat types were merged into six categories: pineland, hammock, freshwater wetland, buttonwood, mangrove and developed (Silvy 1975, Lopez 2001; Table 2.2). Water and Dune habitat categories were deleted from the vegetation map because the Key deer rarely uses those types of habitat.

2.2.1 Pinelands

Pinelands are upland forest communities with an open canopy dominated by the native slash pine (*Pinus elliottii* var. *densa*). Keys pinelands are fire-adapted and dependent on periodic fires for their long-term persistence. Surrounded by wet prairie habitats and/or mangroves, pinelands typically occur on locally elevated areas of bedrock, which may flood seasonally or during extreme storm events. Xeric conditions in this habitat are partly caused by locally low rainfall and the exposed rock ground cover.

The extent of subcanopy development in a pineland is dependent upon the frequency of surface fires. Pinelands on Big Pine Key typically have a well-developed subcanopy consisting of palms (silver thatch palm, *Coccothrinax argentata*; Key thatch palm, *Thrinax morissii*; Thatch palm, *T. radiata*; saw palmetto, *Serenoa repens*) (Bergh and Wisby 1996). Other species found in the pineland understory include strongbark (*Bourreria cassinifolia)*, locust berry (*Byrsonima lucida*), silver thatch palm, pineland croton (*Croton linearis*), rough velvetseed (*Guettarda scabra*), wild sage (*Lantana involucrata*), and long-stalked stopper (*Psidium longipes*). Shrub vegetation in Lower Keys pinelands varies in composition and density. For example, Big Pine Key pinelands have a low and sparse ground covering of grasses and bare limestone, whereas on Cudjoe, Little Pine, and No Name Keys a continuous hardwood understory of six meters height or more is present due to prolonged absence of fire.

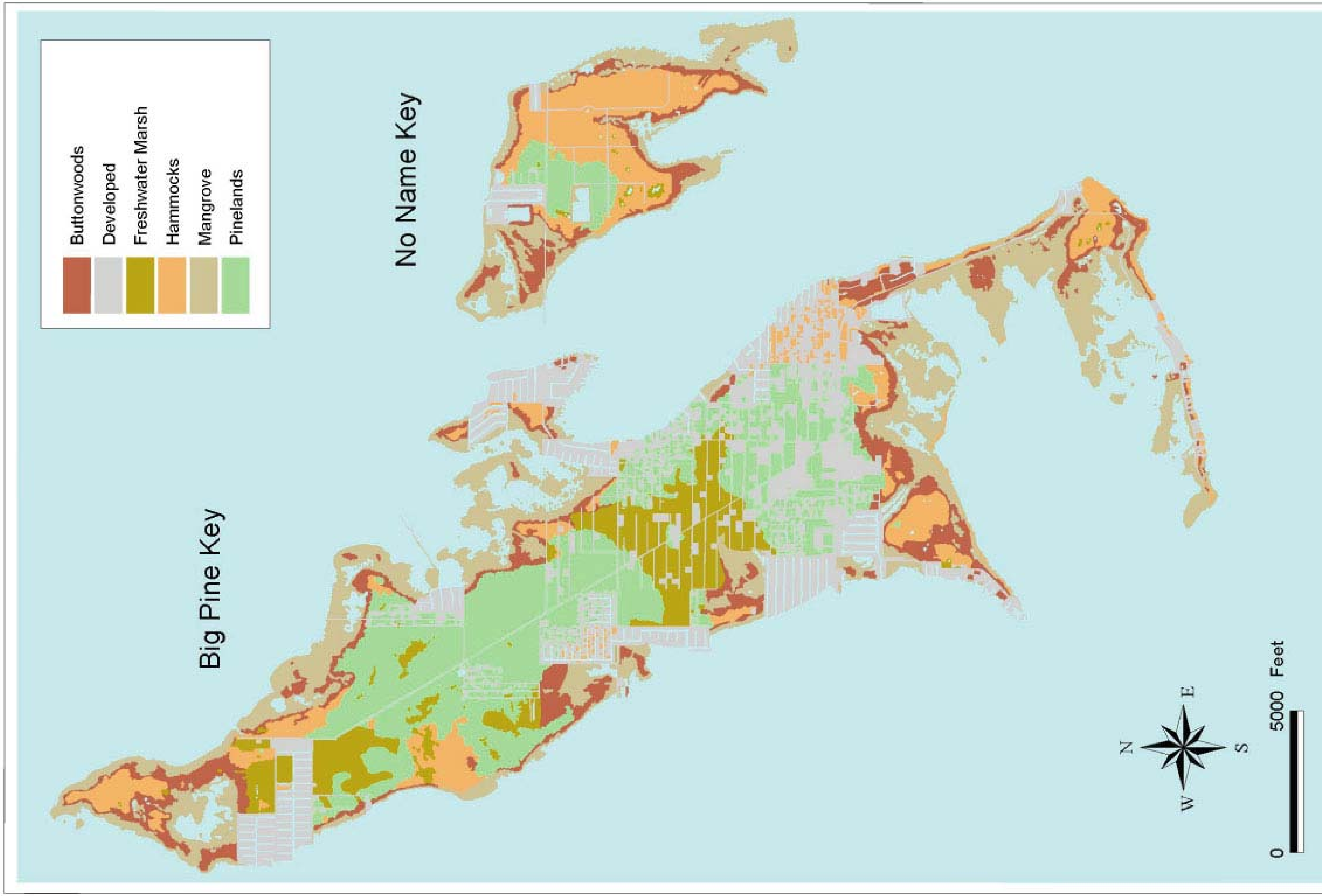

Figure 2.3. Vegetative cover of Big Pine Key and No Name Key

More tropical plant species also occur in the Lower Keys pineland shrub stratum including Caesalpinia (*Caesalpinia pauciflora)*, dune lily-thorn (*Catesbaea parviflora)*, pisonia (*Pisonia rotundata*), and pride-of-Big-Pine (*Strumpfia maritime)*. Plant species from adjacent habitats may invade at the pineland margins. For example, gumbo limbo (*Bursera simaruba*), inkwood (*Exothea paniculata*) and wild tamarind (*Lysiloma latisiliquum*) occur in pinelands sited adjacent to a hammock. Only four plant species endemic to South Florida pinelands (partridge pea, *Chamescista lineata*; small-leaved melanthera, *Melanthera parvifolia*, rockland spurge, *Chamaesyce deltoidea* var. *serpyllum*; sand flax, *Linum arenicola*) occur on Big Pine Key (Ross and Ruiz 1996), likely as a result of water table depth, salinity, and other physical variables.

Pinelands in the Lower Keys have declined markedly in recent history, primarily as a result of development. Coverage in Big Pine Key has decreased by 50% since 1940 (Ross 1989). At present, somewhat extensive pinelands occur on Big Pine, Little Pine, No Name, Cudjoe, and Sugarloaf Keys. Distribution of pineland vegetation in the Keys appears to coincide with the presence of freshwater lenses (McNeese 1998). Other limiting factors on the establishment, growth, and persistence of pinelands appear to be lack of fire (Alexander and Dickson 1970, Snyder et al. 1990, Carlson et al. 1993) and salt-water intrusion into freshwater lenses (Ross et al.1994). Without prescribed burning, the 2,268 acres of pinelands remaining in the Lower Keys could succeed into hardwood hammock in the next 50 years.

Pinelands occur throughout the project area. Key deer preferentially utilize this habitat for the permanent freshwater sources that are critical to survival of the species. Key deer also feed on herbaceous species and the fruits of woody species found in pinelands (Monroe County 1987). The fire regime of pinelands creates an environment of easily accessible food resources for the Key deer (Monroe County 1987).

2.2.2 Hammocks

Along with pinelands, tropical hardwood hammocks represent the climax upland community type in the Florida Keys and are second to pinelands in terms of biodiversity (Ross et al. 1992). Tropical hardwood hammocks in the Florida Keys are closed, broad-leaved forests that occupy elevated, well-drained and relatively fire-free areas. Hammocks in the Lower Keys are more widespread than pinelands, except for Big Pine Key where the area of pineland is greater than that of hammock. Approximately 560 acres of hammock occur on Big Pine Key and 385 acres on No Name Key (Figure 2.3). The greatest limiting factor on hardwood hammocks in the Florida Keys has been human influence, in particular from development.

Canopy trees of the Lower Keys hammocks tend to be smaller than those in hammocks occurring in other parts of Florida, and are often referred to as “low hammock” or “Keys hammock thicket”. Trees commonly found in low hammock generally have a smaller trunk diameter and grow closer together. Species include poisonwood (*Metopium toxiferum*), buttonwood (*Conocarus erectus*), blolly (*Guapira discolor*), Key thatch palm, Spanish stopper (*Eugenia foetida*), wild dilly (*Manilkara bahamensis*), Jamaica dogwood (*Piscidia piscipula*), and white stopper (*Eugenia axillaris*). Other species present on the windward side of low hammocks, referred to as transitional hammock or thorn scrub, include black torch (*Erithalis fruticosa*), saffron plum (*Bumelia celastrina*), sea grape (*Coccoloba uvifera*), blackbead (*Pithecellobium guadalupense*), indigo berry (*Randia aculeata*), tallowwood (*Ximenia americana*), darling plum (*Reynosia septentrionalis*), joewood (*Jacquinia keyensis*), barbed-wire cactus (*Cereus pentagonus*), and prickly pear cactus (*Opuntia stricta*).

Herbaceous plants are largely absent from Keys hammocks. Grasses include low panicum (*Panicum* spp.) and sour paspalum (*Paspalum conjugatum*) (NRCS 1989). In addition, hammocks support a diverse flora of orchids, ferns, bromeliads, and other epiphytes (Snyder *et al.* 1990, USEPA Undated 12), and are home to the federally endangered Key tree cactus (*Cereus robinii*).

Tropical hammocks provide shelter for many animals during periods of high water and also nesting, feeding and roosting sites for many local and migratory birds (NRCS 1989). Key deer primarily utilize this habitat for cover, cool shelter, fawning and bedding (Silvy 1975). Other endangered and threatened species found in these areas include the Lower Keys marsh rabbit and Eastern indigo snake (NRCS 1989). Additionally, tropical hardwood hammocks provide essential habitat for the white-crowned pigeon (*Columba leucocephala*), Schaus' swallowtail butterfly (*Papilio aristodemus ponceanus*), and tree snails (*Liguus* spp.).

2.2.3 Freshwater Wetlands

Throughout the Keys, freshwater wetlands are restricted to areas landward of the seasonal high tide line and in the Lower Keys are found in areas underlain by freshwater lenses (McNeese 1998). The persistence of freshwater ecosystems is limited primarily by freshwater availability, tidal influence, and human activities, including direct and indirect effects of development such as draw-down and contamination (McNeese 1998, Folk et al. 1991, Kushlan 1990, McKenzie 1990, Lapointe 1989). During the dry season, freshwater lenses of Big Pine Key can diminish by as much as 50 percent (Stewart et al. 1989). Freshwater wetlands are located in the northern and central portions of Big Pine Key but are present in one parcel on No Name Key and represent 689.4 and 3.4 acres, respectively.

This habitat type is dominated by sawgrass (*Cladium jamaicense*) and spikerush (*Eleocharis* spp.). Forested freshwater systems in the Keys are generally pinelands with a sawgrass understory (McNeese 1998). Freshwater wetlands are typically found in isolated, seasonally flooded depressions with elevations of +3.0 feet National Geodetic Vertical Datum (NGVD) or less (Kruer 1995) and may be found in conjunction with pinelands. Freshwater wetlands provide critical habitat for several listed species, in particular the Key deer and Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*). These habitats and surface waters represent the only dry season source of freshwater for wildlife (McNeese 1998, NRCS 1989) and play an important role in attenuating nutrients and other contaminants in surface water runoff.

2.2.4 Saltwater Marsh/Buttonwood Marsh

Throughout the Florida Keys, salt marshes and buttonwood associations occur in coastal locations similar to mangrove wetlands (Montague and Wiegert 1990). Salt marshes are non-woody, salt-tolerant communities occupying supratidal zones that are occasionally inundated with salt water. Two types of salt marsh are found in the Florida Keys, low marsh and high marsh. Low marsh species include salt-tolerant herbs such as glasswort (*Salicornia* spp.) and Keygrass (*Monanthochloe littoralis*), while high marsh is dominated by Gulf cordgrass (*Spartina spartinae*), fringe rushes (*Fimbrystylis* spp.), and sea-oxeye daisy (*Borrichia frutescens*) (McNeese 1998).

Buttonwood associations border high marsh communities and have similar ecological characteristics (McNeese 1998). Plant species that inhabit this community prefer low-energy waves with little tidal disturbance. Buttonwood forests are dominated by the silver buttonwood (*Conocarpus erectus)*. Other species include salt tolerant herbaceous perennials and woody shrubs such as fringe-rushes, Keygrass, Gulf cordgrass, and seashore dropseed (*Sporobolus virginianus*). There are approximately 685 acres of buttonwood marsh on Big Pine Key and 170 acres on No Name Key (Figure 2.3).

Salt marsh/buttonwood marsh communities provide important habitat for terrestrial species including the federally endangered Lower Keys marsh rabbit, silver rice rat (*Oryzomys argentatus*), and diamondback terrapin (*Malaclemys terrapin*). Buttonwood areas provide herbaceous foods and loafing areas for Key deer. Common residents include polychaetes, gastropod mollusks, bivalve mollusks and crustaceans. Birds tend to use the marsh for feeding rather than for nesting however few species of birds, fish, reptiles, or mammals can be considered residents of salt marshes, and larger longer-lived organisms are not tolerant of the environmental fluctuations (Montague and Wiegert 1990).

2.2.5 Mangroves

Mangrove communities consist of facultative halophytes, which are tolerant of anaerobic saline soils and tidal inundation. Three species are found in Florida: the red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), and white mangrove (*Laguncularia racemosa*).

In general, the zonation of mangrove communities is regulated by elevation. Red mangroves occur in the middle and lower intertidal zone and upper subtidal zone. Black mangroves dominate the upper intertidal zone and are generally found between the red and white species. White mangroves occur on the landward edge of mangrove forests, throughout the intertidal and in the upper portions of the swamp. Ground cover within a mangrove forest consists of leaf litter and decomposing forest debris.

Throughout the Florida Keys, mangrove forests form the predominant coastal vegetation community. Mangroves are found along the edges of shorelines, bays and lagoons and on overwash areas throughout the Keys. Major limiting factors on mangrove establishment, growth and persistence in the Florida Keys appear to be water quality, substrate, and development (Lewis 1980, Snedaker and Lugo 1973, Strong and Bancroft 1994, Odum et al. 1982). Mangrove habitat occurs on approximately 1,495 acres of Big Pine Key and 374 acres of No Name Key (Figure 2.3).

Mangrove communities in the Florida Keys provide essential habitat for numerous ecologically and economically important species (FWC Undated 7). The leaves and fruits of red and black mangroves are a primary food source for the Key deer, which spend considerable time foraging in tidal wetlands (Monroe County 1987, Silvy 1975). In South Florida, mangroves are important habitat for at least 220 fish species, 24 reptile and amphibian species, 18 mammal species, and 181 bird species (Odum *et al.* 1982), and provide nesting habitat for a number of threatened and endangered species, including the white-crowned pigeon (*Columba leucocephala*). Additionally dissolved organic matter from mangroves serves as an alternate food source, the basis for heterotrophic microorganism food webs, and a source of chemical cues for estuarine species (Snedaker 1989).

2.3 Scientific Basis of the HCP: The Key Deer Population Viability Analysis (PVA) Model and Its Application

2.3.1 Field Studies of the Population Dynamics of the Key Deer

Prior to 1998, Silvy (1975) had conducted the most recent, comprehensive population study of Key deer population dynamics in the early 1970s. Between 1998 and 2001, Lopez (2001) studied the Key deer population on Big Pine Key and No Name Key. To determine the fate of individual Key deer through time, Lopez placed radio transmitters on over 200 deer (Table 2.3) and monitored the status of individual deer for up to three years. Information on individual deer provided and assessment of the year-to-year probability of mortality and fecundity. Radio telemetry data also provided a clear picture of habitat utilization, deer movement, and deer distribution in the study area.

Table 2.3. Gender and age-classes[1] of radio collared Key deer in Big Pine Key and No Name Key, 1998-1999 (after Lopez, 2001)

	Adults	Yearlings	Fawns	Total
Male	52	35	9	96
Female	82	32	12	126
Total	134	67	21	222

[1] Fawns: <1 year old; Yearlings: 1-2 years old; Adults: >2 years old.

From March 1998 to December 1999, Lopez (2001) also performed weekly censuses along 10 miles of roads and bi-monthly censuses along 44 miles of roads in Big Pine Key and No Name Key. The censuses provided information on deer number and density.

2.3.2 Development of the Key Deer Population Viability Analysis Model

Numerous models have been developed for estimating the risk of extinction for small populations (Akcakaya 2000). A Population Viability Analysis (PVA) model is a collection of methods for evaluating the threats faced by populations or species, their risks of extinction or decline, and their chances for recovery (Akcakaya and Sjogren-Gulve 2000). Species viability is often expressed as the risk or probability of extinction, population decline, expected time to extinction, or expected chance of recovery (Akcakaya and Sjogren-Gulve 2000). PVA models attempt to predict such measures based on demographic and habitat data. PVA modeling involves the use of computer simulations to assess extinction threats and is becoming one of the primary tools for the classification of threatened and endangered species by wildlife management agencies nationwide.

A PVA model was developed to evaluate development impacts on the Florida Key deer population. Key deer movements, habitat utilization, ecology and demographic data were used to construct the model (Lopez 2001). The PVA model included two main components: a) a matrix model of population dynamics and b) a spatial habitat model of carrying capacity and secondary impacts.

Matrix Model

Quantitative information on mortality and fecundity for deer of different stages (e.g., fawn, yearling, adult) was used to create a matrix model, which allows for simulating the fate of the population under different scenarios (Lopez 2001). In a matrix model, changes in mortality or fecundity result in changes in the way the population size changes through time. A stage-based matrix model of population dynamics represents the dynamics of the population as a function of annual estimates of fecundity (average number of fawns produced by females) and survival (probability of surviving from one year to the next). The Key deer model is applied only to females and takes the form:

$$\begin{bmatrix} & F_y & F_a \\ S_f & & \\ & S_y & S_a \end{bmatrix},$$

Where S_f, S_y, and S_a are fawn, yearling, and adult survival, respectively, and F_y and F_a are yearling and adult fecundity estimates, respectively.

The matrix model allows for the analysis of stochasticity (i.e., the haphazard, year-to-year variation in fecundity and survival associated with changes in the environment). Stochastic events are particularly significant for small populations and, therefore, the model includes estimates of the variability of the population parameters. For example, annual female survival and variance estimates for each stage class were determined using a known-fate model framework in the computer program MARK (White and Burnham 1999, Lopez 2001). The model also allows for evaluating the effects of stochastic events, such as hurricanes. A detailed discussion of the methodology to estimate model parameters is found in Lopez (2001, 2003) and Lopez et al. (2003).

Spatial Model

While the matrix model represents the overall dynamics of the Key deer population in the study area, the spatial model represents the location-specific contribution to the matrix model parameters. For example, localized changes in habitat quality and distribution, or in the number and location of paved roads may affect both fecundity and survival.

The spatial model also sought to address the anticipated impacts of development. Urban development causes two main types of impacts on the Key deer:

1. A change in carrying capacity. Urban development displaces and modifies Key deer habitat, therefore affecting the capacity of the remaining habitat to sustain Key deer.
2. An increase in human-induced Key deer mortality. A change in the amount of development and resulting changes in the human population may in turn result in changes in the mortality of Key deer caused by motor vehicle collisions, entanglement in fences, and other human-related effects.

Therefore, in order to address impacts to carrying capacity and mortality, the spatial model includes a carrying capacity and a "harvest" (i.e., human-induced mortality) grid. The grids represent the entire study area as an array of 10x10 meter cells; each cell's value represents its contribution to the total carrying capacity or harvest of the study area.

A weighting factor grid supported the development of the carrying capacity and harvest grids. The objective of the weighting grid was to address location-specific conditions that affect carrying capacity and harvest. For example, two grid cells of the same vegetation type may contribute differently to the carrying capacity of the Key deer depending on their proximity to canals: a pineland cell located in the middle of a large pineland area would provide better habitat to the Key deer that an isolated pineland cell surrounded by canals. Similarly, development of a pineland cell near US-1 would create a lesser vehicle collision impact (due to shorter travel distance to US-1) than development of a pineland cell located far from US-1 (because of the longer travel distance to US-1).

Six parameters entered into the weighting factor grid (Figure 2.4):

- House density. Development in areas with areas with higher house density would have a lesser impact on the deer than development in areas of lower house density.
- Deer corridors. Development in Key deer corridors would have a lesser impact than development in areas outside Key deer corridors.

- Patch quality: Development in larger, uninterrupted habitat areas would have a lesser impact on the Key deer than development in smaller, fragmented habitat areas.
- Deer density: Development in areas of low Key deer density would have a lesser impact than development in areas of high density.
- Distance from US-1. Development near US-1 would have a lesser impact on the Key deer than development farther from US-1.
- Water barriers. Development in areas without canals would have a lesser impact than development in areas with canals.

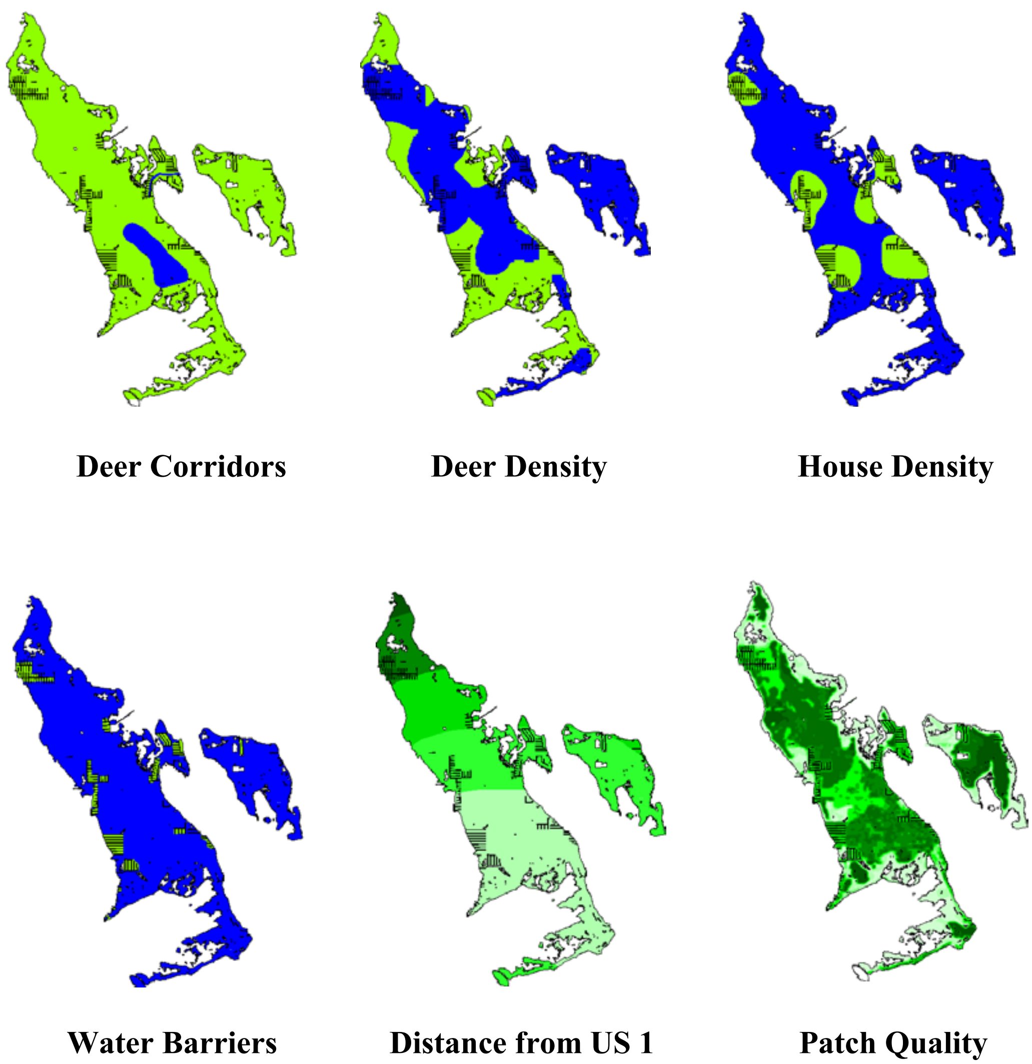

Figure 2.4. Six grid layers used to generate weighting factor grid (darker shades = higher deer value)

Because more than one factor may affect the value of a given cell, the final cell value in the weighting factor grid was the average of the six parameters, where 0 represented the lowest value to the Key deer and 2 represented the highest value to the Key deer.

The final carrying capacity grid (Figure 2.5) represents the contribution of each 10x10 meter cell to the total carrying capacity of the study area after applying the weighting factor. Similarly, the final harvest grid represents the proportional contribution of each 10x10 meter cell to the total harvest in the study area.

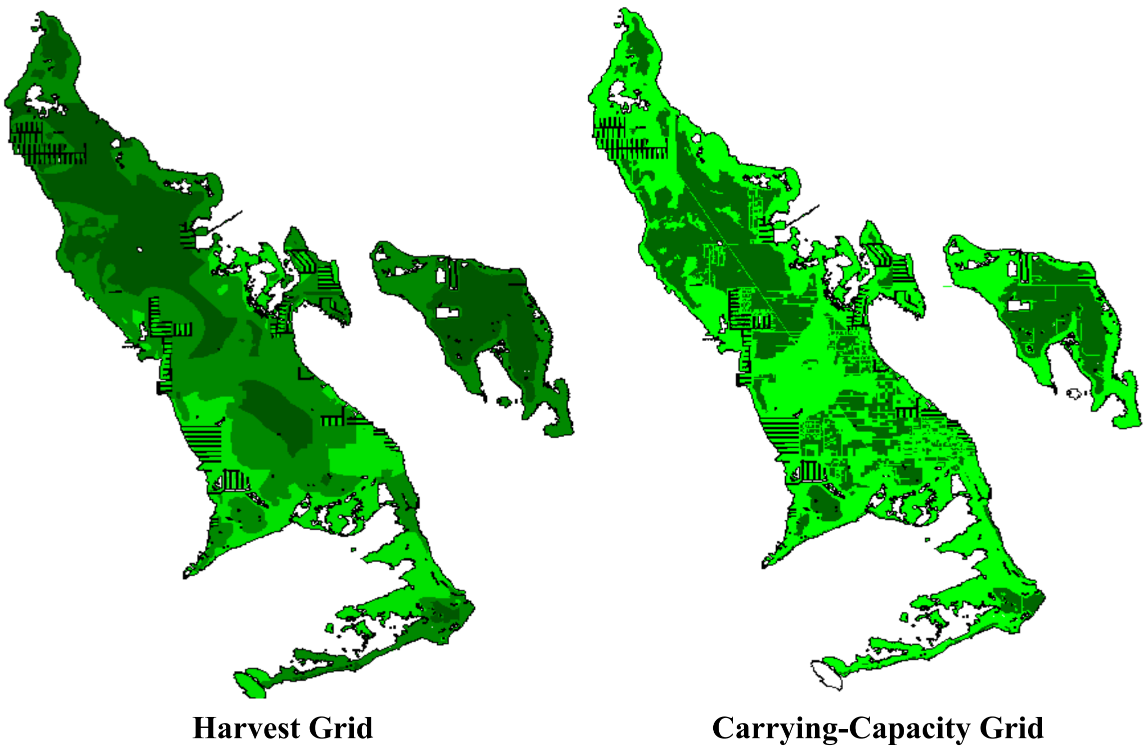

Figure 2.5. Key deer PVA model grid layers. For any given scenario, the location and intensity of development affect both the carrying capacity and the mortality of the Key deer (darker shades = higher deer value).

2.3.3 <u>PVA Model Analysis and Results</u>

The final PVA model includes the matrix model of population dynamics and the spatial model, which allows for addressing development impacts. The program RAMAS Metapop (Applied Biomathematics, Inc.) was used to run the model. The model provides estimates of population size, probability of extinction, and other risk estimates.

In a model "run", the initial population number by stage class, is multiplied by the matrix; the result represents the number of Key deer in each stage class one year later. This new number is multiplied by the matrix again, to generate the population number for year 2. The model run simulates 100 years. The process is repeated 10,000 times. Each time, the computer randomly varies matrix parameters and hurricane probabilities, within documented ranges (Lopez 2001) to account for stochastic events. The final model run result represents the average of the 10,000 iterations.

To estimate the effects of increasing levels of development on the Key deer population, 10 scenarios were evaluated with the Key deer PVA model (Table 2.4). For any given scenario, the model chose the least valuable vacant parcels for development (parcels with the lowest K, H). As parcels are selected, the spatial model calculated the change in carrying capacity (K) and harvest (H). New K and H values, which represent the direct effects of development, are then input into the matrix model. Therefore, the model run simulates the effect of development on the Key deer population through time.

Table 2.4. Effect of development on the Key deer.

Scenario	Number of Residential Parcels Developed[2]	Habitat Loss[3] (decrease in K)	Total Harvest[4] (increase in H)	Risk[5] (probability) of Extinction in 100 years	Risk[5] (probability) of falling below 50 females at least once in 50 years [3]	Additional average annual mortality[5]
No Action	0	0	0.00	0.0005	0.0230	0
S1 [1]	0	0	(-0.80)	0.0005	0.0230	0
S2	200	4	(-0.38)	0.0005	0.0230	0
S3	300	6	(-0.07)	0.0005	0.0230	0
S4	400	8	0.27	0.0005	0.0276	0.28
S5	500	10	0.67	0.0005	0.0291	1.21
S6	600	12	1.20	0.0011	0.0459	2.32
S7	700	14	1.79	0.0021	0.0653	3.23
S8	800	24	2.10	0.0023	0.0774	3.50
S9	900	27	2.47	0.0037	0.0956	3.82
S10	1000	30	2.91	0.0068	0.1198	4.13

1 S1 includes US-1 projects: wildlife underpasses, intersection improvement, and three-lanes. The combined effect of these projects is a surplus of three Key deer per year. All other scenarios include these projects.
2 The model selected parcels with lowest total habitat value to the Key deer.
3 From the carrying capacity grid in the spatial model. It is an input to the matrix model.
4 From the harvest grid in the spatial model. It is an input to the matrix model. H in scenarios S1, S2 and S3 is a surplus caused by the overall effect of US-1 projects (i.e., surplus of three deer per year, per USFWS 1999). Net harvest was kept at 0 for these scenarios; therefore the no net change in model results (risk and additional mortality).
5 Results from matrix model run. Refers to females only.

The model runs provide an estimate of the risk of extinction in 100 years and the risk of the population falling below 50 individuals (females) at least once in 50 years (Table 2.2). Both are expressed as probabilities. The model also estimates the average additional human-induced mortality (number of female deer).

Results suggest that the probability of extinction of the Key deer in 100 years is less than one percent, even in the presence of levels of development unlikely to occur in the project area (Table 2.4). Model results also indicate the probability that the Key deer population will fall below 50 females at least once in 50 years is 2.3 percent even with no further development. The model suggests that annual human-induced mortality is likely to increase with the intensity of development.

The matrix model is more sensitive to changes in H than to changes in K. In turn, changes in H are highly correlated with predicted impacts measured as either the risk of falling under 50 individuals in 50 years or additional annual human-induced mortality. The equations that relate H with these impact assessment variables are:

$$\text{Percent Risk}_{(50)} = 2.2e^{0.58H}, \text{ and}$$

$$\text{Additional Annual Human-Induced Mortality (males plus females)} = -0.65H^2 + 4.85H - 0.34$$

In both cases, the equations explain 99% of the variance; therefore, H is an excellent predictor of development impacts to the Key deer.

2.3.4 Application of the PVA Model to the Habitat Conservation Plan

First, the spatial component of the PVA model provides a reliable predictor of development impacts on the Key deer: Harvest (H), which is highly correlated with estimates of impacts. Throughout this HCP, H is used as the measure of impact and incidental take on the Key deer.

The spatial model provides the H value of any given parcel. H for a parcel is the sum of the H value for each 10x10-m grid cell inside the parcel. A cell is counted within a parcel if >50% of its area is inside the parcel. To estimate the H value of a development activity, the H value from the H grid is multiplied by a factor that accounts for the traffic generated by specific land uses (Table 2.5). The multiplier is based on traffic generation because vehicle collisions with Key deer is, bar for, the most important human-related cause of mortality for the Key deer. Therefore, the H impact areas can be readily measured for any parcel and any type of development activity.

Table 2.5. H multiplier for land use development categories[1]

Land Use	Average Daily Trip Generation[2]	H Multiplier
Single family residential	9.5	1
Fences only	--	0.2[3]
Auxiliary uses	--	0.2[3]
Retail	70.0	7.4 (per 1,000 sq. ft.)
Hotel/Motel	7.9	0.8 (per room)
Office	5.9	0.6 (per 1,000 sq. ft.)
Institutional	13.0	1.4 (per 1,000 sq. ft.)
Industrial	5.0	0.5 (per 1,000 sq. ft.)
Recreational	67.0	7.0

[1] The multiplier is based on traffic generation because vehicle collisions with Key deer is the most important human-related cause of mortality for the Key deer.
[2] Average daily trips generation was estimated from the Institute of Traffic Engineers Manual; daily trip generation by land use has not been verified for the Florida Keys.
[3] Fences and auxiliary uses, as defined in the Monroe County Land Development Regulations, are assumed to cause no additional traffic impacts; they were assumed to cause habitat loss (change in K), which has a lesser effect on the matrix model than changes in H.

For example, to estimate the H impact of a recreation park on a 5-acre parcel, first the spatial model is queried to obtain the H for the parcel; then H is multiplied by the corresponding factor, 7.0 in this case (Table 2.5), to obtain the total H for the proposed development. For land uses in which the factor depends on the square footage of development, the procedure is the same, but the factor is applied after the square footage is taken into account. For example, a 2,500 sq. ft. expansion of a retail site would result in a total H equal to: H for the parcel from spatial model x (2,500/1,000 sq. ft.) x 7.4 (retail multiplier).

Second, the Key deer studies done under this HCP and the resulting spatial model provided the basis to develop a conservation priority classification for undeveloped lands in the study area. The private undeveloped lands in the study area are classified into three "Tiers" (Table 2.6 and Figure 2.6). Tier 1 lands are high quality habitat. Tier 3 lands are the lowest quality habitat. The tier classification provided support to determining the location of potential development and prioritizing mitigation areas.

Table 2.6. Tier classification system (vacant privately-owned lands)

Tier	Description	Area (acres) Big Pine Key	No Name Key
1	Lands where all or a significant portion of the land area is characterized as environmentally sensitive and important for the continued viability of HCP covered species (i.e., high H). These lands are high quality Key deer habitat, generally representing large contiguous patches of native vegetation, which provide habitat for other protected species as well.	973.4	217.0
2	Scattered lots and fragments of environmentally sensitive lands that may be found in platted subdivisions. A large number of these lots are located on canals, which are of minimal value to the Key deer and other protected species since the canal presents a barrier to dispersal.	101.6	0
3	Scattered lots within already heavily developed areas, which provide little habitat value to the Key deer and other protected species. Some of the undeveloped lots in this Tier are located between existing developed commercial lots within the US-1 corridor or are located on canals.	58.5	0
	Total	1133.5	217.0

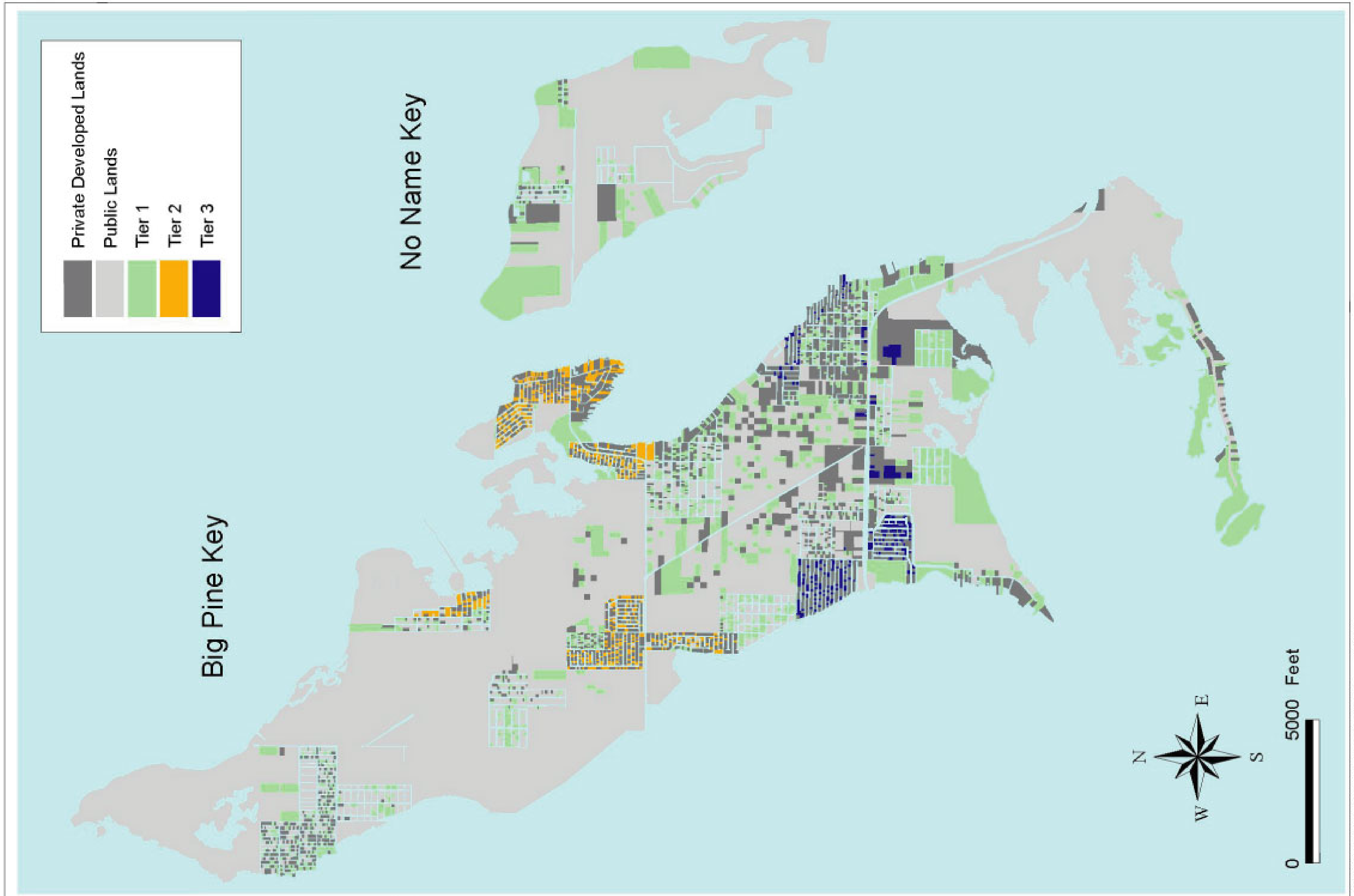

Figure 2.6 Tier classification system in the project area